Audio Programming 2

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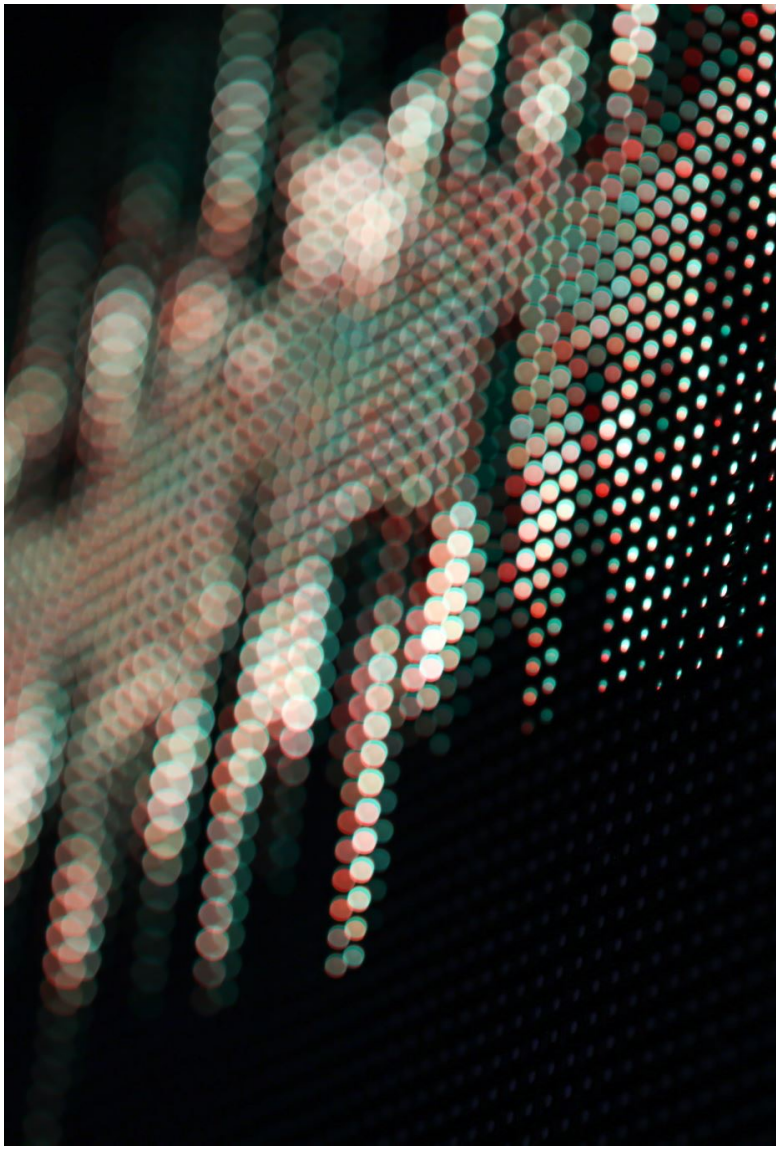
Today's Lecture

- What is modulation?
- What are Modulation Effects made up of?
- What is an LFO?
- Detailed examples of Modulation Effects
  - Flanger
  - Phaser
  - Chorus
- Creating a Flanger on BELA



What is Modulation?

The word modulate means to change.

Modulation effects utilize the changing of an audio parameter (usually a delay parameter) over time to create interesting sonic characteristics. Modulation effects include tremolo, vibrato, chorus, flanger, pitch shifter, and phaser.

Strictly speaking a modulation effect must have at least two signals. Therefore, tremolo and vibrato are not TRUE modulation effects but are often categorized as such by audio engineers.

In most cases an input signal is duplicated, sometimes multiple times, and these are then modified then blended back with the original. In others the audio signal is modified by a carrier wave.

Many different parameters can be modulated to create unique effects, these include delay time, phase and pitch.

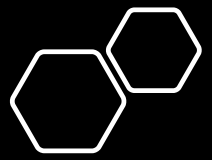
What Makes up a Modulation Effect?

Most modulation effects are unique combinations of three common DSP “building blocks”, delay lines, low frequency oscillators and wet/dry mixers.

Delay lines are used to modify the timing of the duplicate signals.

Low frequency oscillators are used to control the speed of the modulation. This parameter is often called the *Rate*.

Wet/dry mixers are used to ratio of the modulated signal (wet) and the original signal (dry). This parameter is often called the *Depth*.



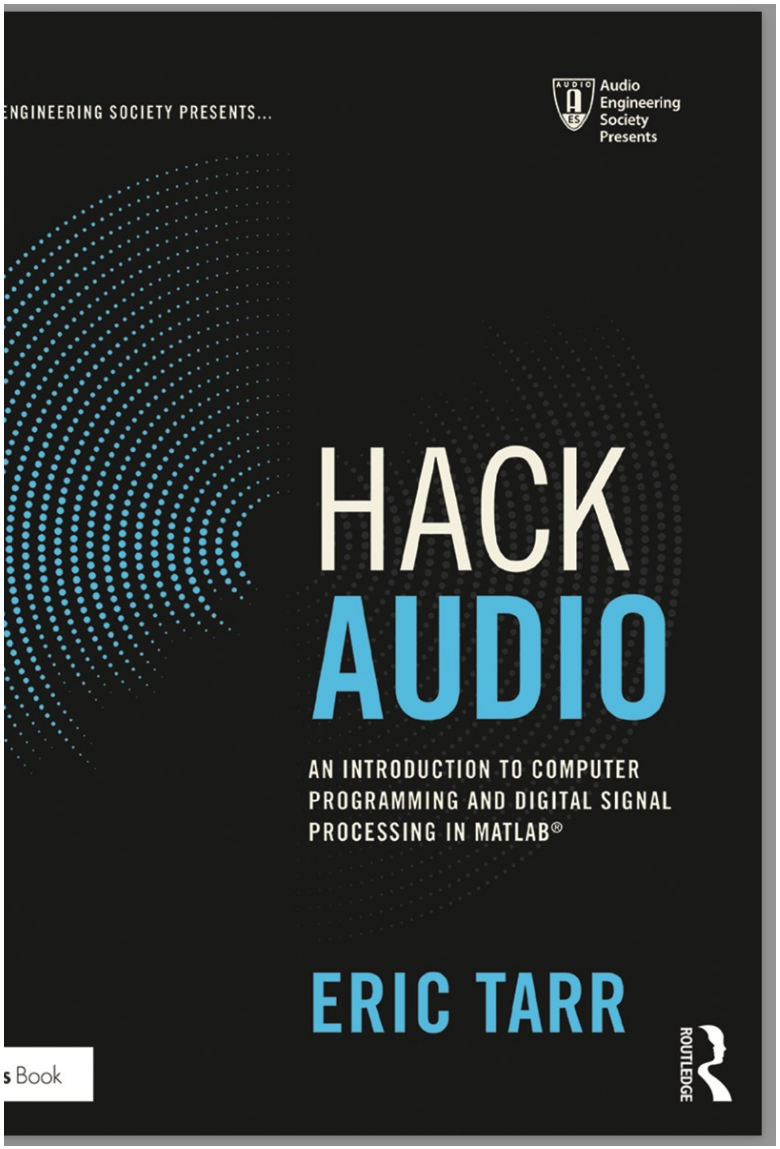
LFOs

Low Frequency Oscillators or LFOs are used to help automatically modulate a signal.

LFOs are periodic signals which are typically below the audible spectrum (< 20Hz) and are used to modulate audio parameters.

It is important to note that they aren’t usually used to generate sound.

Like other signals used in synthesis, LFOs are commonly found as sine, square, sawtooth and triangle forms.



Reference

The following examples of modulation effects algorithms and their block diagrams is based on Eric Tarr – Hack Audio Chapter 15.

You can use the MATLAB examples in this book to help you code (although you will need to convert this to C++ yourself).

Example Sine Wave LFO

For modulated delay effects, the amplitude of the LFO is used to change the delay. If the amplitude of the LFO increases, then the delay time increases. If the amplitude of the LFO decreases, then the delay time decreases.

As an example, consider a sine-wave LFO based on the following function:

$$3 \cdot sin(2 \cdot \pi \cdot f \cdot t) + 5$$

Here, the amplitude of the sine wave is offset, such that it is oscillating with an amplitude range centred around a value of 5. Therefore, this LFO could be used to create a delay time centred around 5 samples (or could be converted to other time units, 5 milliseconds or 5 seconds).

The amplitude of the sine wave increases to a maximum of 8 and decreases to a minimum of 2. As the amplitude changes, this can be used to change the delay time between 8 samples and 2 samples. Typically, the frequency, f , of the LFO for musical effects can range from 0.1–10 Hz.

Exercise 1

Create a real-time sine wave LFO on your BELA board.

- Create a BELA GUI
- Use two sliders to set the maximum amount of offset and its range.
- You the formula directly, don’t worry about computational efficiency.

Note: This LFO will be used later to control delay time modulation. However, the delay will will NOT need to be fractional and can either round to the nearest neighbour sample or truncate.

Listen to several Modulation Effect Guitar Pedals

https://www.youtube.com/watch?v=MpHA8hoc9SU

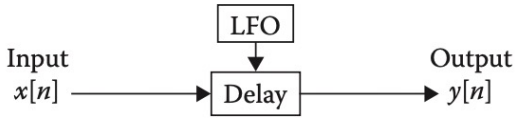
Vibrato

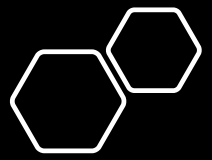
The series modulated delay is called **vibrato** when used as an audio effect.

Although this effect is based on time delay, this effect is not typically used to create an audible echo.

Instead, vibrato introduces slight changes to the pitch of a signal when the delay is increasing or decreasing. When the delay is increasing (i.e., getting longer), it is as if the signal is slowing down.

Therefore, the period of the signal is elongated and the frequency decreases. When the delay is decreasing (i.e., getting shorter), it is as if the signal is speeding up. Therefore, the period of the signal is shortened and the frequency increases.





Exercise 2

Create a vibrato effect on BELA.

- You will first need to create a circular buffer class to use as a delay line.
- You can then use this buffer and the LFO created in Exercise 1 to implement a vibrato effect.
- Experiment with different LFO offsets and ranges, how does this affect the sound?

Chorus

One audio processor created using a parallel modulated delay is the **chorus** effect.

Conceptually, the chorus effect is meant to process an individual “voice” and make it sound like an ensemble is performing the same part.

It is as if a part has been double- or triple-tracked (i.e., recorded two or three times) and layered to add a perceived “thickening” to the sound.

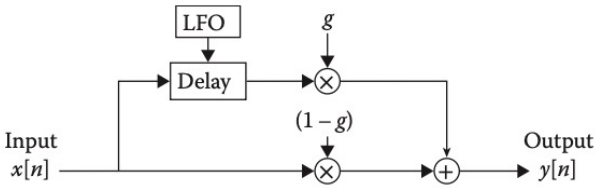
When multiple people play the same part, there are inevitably small differences between the signals they produce, as each musician may start and stop notes at slightly different times.

Chorus

The chorus effect is closely related to the vibrato effect.

Chorus is created by blending the unprocessed dry input signal with the vibrato effect in parallel.

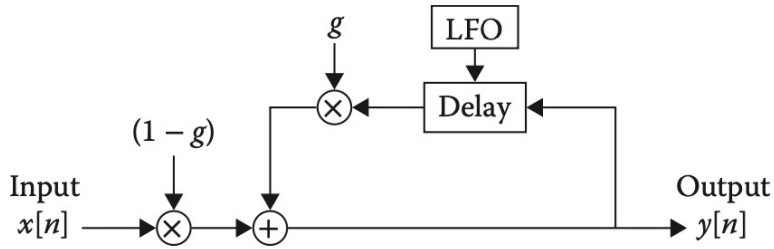
The delay time of the effect typically has a range between 10–50 ms. This range is close to a listener's echo threshold, such that the effect does not create an audible echo due to a longer time delay.

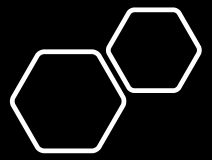


Flanger

A flanger is also created the same way as a chorus, except this time the delay time is much shorter, typically less than 50 samples (dependent on sample rate that is up to about 20ms).

The result is a sort of whooshing effect as various peaks and valleys are created in the sonic spectrum. Flanging is also known as comb filtering due to the comb-like appearance of this effect.





Exercise 3

Use the same building blocks to create:

A single tap modulated delay. Make this switchable between feedforward and feedback configurations.

Change the Offset and Range to create flanging and chorus effects

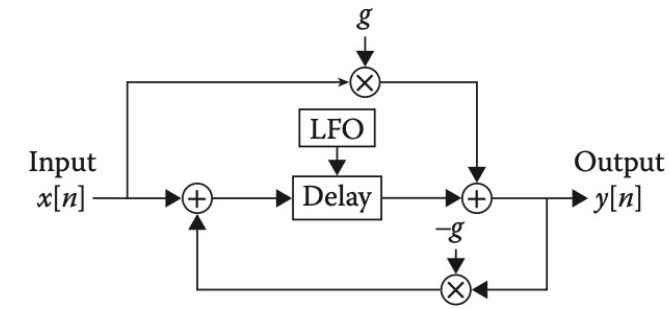
Phaser

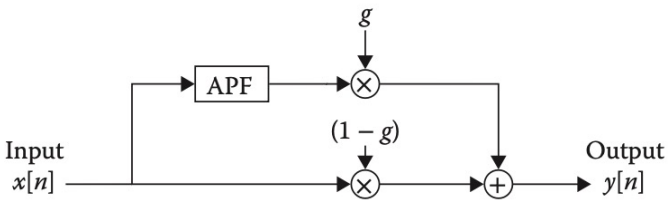
The **phaser** audio effect is created by modulating the delay time of an All Pass Filter.

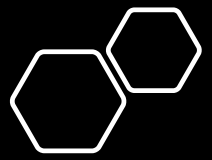
This effect uses constructive and destructive interference to decrease the amplitude of a narrow range of frequencies.

By using the all pass filter in parallel with the dry signal, destructive interference occurs for frequencies near where the APF introduces a 180◦ phase shift. Furthermore, constructive interference occurs for frequencies near where the all pass filter introduces a phase shift of 0◦ or 360◦.

It sounds similar tonally to a flanger but often exhibits less extreme ”whoosing” and more of a “rotating” feel.







Exercise 4

Create an All Pass Filter class, which has a delay line instance (composition).

Use all of your LFO and APF to create a Phaser effect.